

**Identify and Evaluate the Cost per Unit to Grow
Cultured Corals from Acquisition to Reattachment for
Reef Restoration Sites**

Final Report

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PROJECT GOAL

The overall goal of this project was to identify and evaluate the cost per unit (coral colony) to grow cultured corals from acquisition to reattachment for reef restoration sites. This project was initiated in September 2005 and funded for three years by the Florida Keys National Marine Sanctuary (FKNMS) to collect production cost data for culturing corals in a land-based nursery at Mote's Tropical Research Laboratory in Summerland Key. Costs associated with acquisition of corals from the FKNMS coral nursery in Key West and from a hypothetical field grounding site were identified. Variable costs associated with culturing coral colonies in a land-based environmentally controlled laboratory were documented and estimated cost per colony are presented. Costs associated with replanting coral fragments to a hypothetical field nursery site were identified. Future efforts will be directed toward developing an integrated spreadsheet to identify the costs to operate a land-based hatchery/nursery to produce corals for reef restoration.

PROJECT ACCOMPLISHMENTS

Task 1: Document the costs associated with coral acquisition.

Corals were acquired from two sources during this project: Boat groundings and rescued corals from the Key West Naval Wall. The estimated costs associated with retrieving coral fragments from the Key West nursery site, moving them to the land based nursery, and transferring the corals to temporary holding raceway systems is documented in Table 1. The costs associated with retrieving coral fragments from a hypothetical grounding site near Looe Key and transferring the corals to temporary holding raceway systems (Figures 1 and 2) is documented in Table 2.



Figure 1. Outdoor covered raceways for acclimation and quarantine.

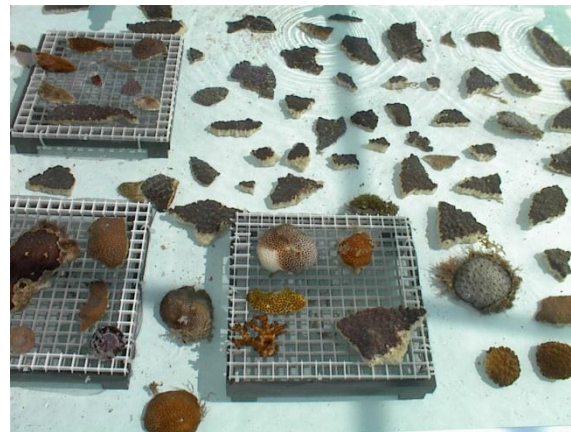


Figure 2. Recently acquired corals in raceway prior to fragmentation and mounting.

Table 1. Cost associated with acquisition of coral colonies from Key West field nursery and transport to Summerland Key Coral Culture Facility.

<u>Input</u>	<u>Units</u>	<u>Cost</u>	<u>Total Cost</u>
Transportation	Miles = 50 roundtrip	\$0.442/mile	\$22
Labor (transportation)	2 technicians X 2 hr	\$14/hr	\$56
Labor (collecting dives)	2 technicians X 6 hr	\$14/hr	\$168
Labor (transfer to tanks)	2 technicians X 2 hr	\$14/hr	\$56
Supplies (coolers, bags, O ²)			\$20
Equipment use	Tank rental, dive gear		\$25
Total			\$347

Table 2. Cost associated with acquisition of coral colonies from a hypothetical grounding site near Looe Key and transport to Tropical Research Laboratory (Summerland Key).

<u>Input</u>	<u>Units</u>	<u>Cost</u>	<u>Total Cost</u>
Transportation - Boat	Boat Use = 1 Day	\$225/day	\$225
Labor (collection & transport)	2 technicians X 8 hr	\$14/hr	\$224
Labor (Boat Captain)	Boat captain X 8 hr	\$23/hr	\$184
Supplies (coolers, bags, O ²)			\$20
Equipment use	Tank rental, dive gear		\$25
Total			\$678

Task 2: Document the costs associated with culturing coral fragments in an aquaculture facility.

During the project, the Coral Aquaculture Research Team at Mote Marine Laboratory's Tropical Research Laboratory (TRL) on Summerland Key maintained coral colonies from as many as 31 species of scleractinian corals (see Table 3) inside an Environmentally Controlled Laboratory (ECL) and in outdoor, shade-cloth covered flow-through raceway systems. The ECL is an insulated room (Figures 3 and 4) that has 3 small air conditioners to maintain room and tank temperature, 100-gallon (3) and 200-gallon (3) tanks, recirculating filtration systems (1 per tank), powerheads to create water currents (1 per tank), heaters (1 per tank), metal halide lamps (1 per tank), and a small workspace where water chemistry analyses and food preparation is conducted.



Figure 3. ECL tank systems and laboratory.



Figure 4. Experimental tank (100 gallon) in ECL.

The ECL tank systems provided optimal culture conditions for most of the coral species examined. Healthy coral specimens were maintained in the ECL for over 5 years and many corals were fragmented and placed in ECL tanks or in outdoor raceway systems. Two experimental trials were conducted to evaluate the effect of light on growth. General observations of growth and health condition of corals in the ECL was monitored on a daily basis over the 3-year period. The first experimental trial was conducted with 3 coral species (*Acropora cervicornis*, *Montastrea annularis*, *Montastrea cavernosa*) and a second, more carefully controlled, experimental trial was conducted with 4 coral species (*A. cervicornis*, *A. palmata*, *M. annularis*, *M. cavernosa*).

Corals were also maintained at TRL in outdoor, shade-cloth covered flow-through raceway systems. Filtered seawater was provided from a saltwater well to the raceways and discharged into the adjacent canal. The constant exchange of water and shade-cloth covers allowed us to maintain suitable water temperatures and provide natural light to the corals. Future plans for TRL include the construction of a ventilated greenhouse with separate raceway systems to support large-scale production of corals from upper, middle and lower Keys grounding sites.

Table 3. List of coral species cultured during the project and collection site and date.

Coral Species		Collection site/date
1	<i>Acropora cervicornis</i>	Pigeon or Looe Key/pre 2003; Navy Pier Key West/04;Looe Key/04
2	<i>Acropora palmata</i>	Looe Key/04; Naval Pier Key West/04
3	<i>Agaricia humilis</i>	Navy Pier Key West/04,06
4	<i>Cladocora arbuscula</i>	Navy Pier Key West/04,06
5	<i>Colpophyllia natans</i>	Navy Pier Key West/06
6	<i>Dichocoenia stokesi</i>	Navy Pier Key West/04,06
7	<i>Diploria clivosa</i>	Navy Pier Key West/04,06
8	<i>Diploria strigosa</i>	Navy Pier Key West/04,06
9	<i>Eusmilia fastigiata</i> 'flower'	Navy Pier Key West/06
10	<i>Favia fragum</i>	Navy Pier Key West/04,06
11	<i>Isophyllastrea rigida</i>	Pigeon or Looe Key/pre 2003
12	<i>Manicina</i> sp. (rose coral)	? Possibly Navy Pier Key West/06
13	<i>Meandrina meandrites</i>	Pigeon or Looe Key/pre 2003; Navy Pier Key West/04
14	<i>Montastraea cavernosa</i>	Navy Pier Key West/04,06
15	<i>Montastraea annularis</i>	Navy Pier Key West/06
16	<i>Montastraea</i> sp.	Pigeon or Looe Key/pre 2003; Navy Pier Key West/04
17	<i>Mussa angulosa</i>	Navy Pier Key West/06
18	<i>Mycetophyllia aliciae</i>	Navy Pier Key West/04
19	<i>Oculina diffusa</i>	Navy Pier Key West/04
20	<i>Oculina robusta</i>	Navy Pier Key West/04
21	<i>Phyllangia americana</i>	Navy Pier Key West/06
22	<i>Porites astroides</i>	Pigeon or Looe Key/pre 2003; Navy Pier Key West/04;1 Looe Key/04,06
23	<i>Porites divaricata</i>	Pigeon or Looe Key/pre 2003, Navy Pier Key West/06
24	<i>Porites porites</i>	Pigeon or Looe Key/pre 2003
25	<i>Porites</i> sp. (flat)	Pigeon or Looe Key/pre 2003 & Navy Pier Key West/04
26	<i>Scolymia cubensis</i>	Navy Pier Key West/04,06
28	<i>Siderastrea radians</i>	Pigeon or Looe Key/pre 2003; Navy Pier Key West/04,06
29	<i>Siderastrea siderea</i>	Pigeon or Looe Key/pre 2003;Navy Pier Key West/04,06
30	<i>Solenastrea bournei</i>	Navy Pier Key West/03,06); Looe Key/04
31	<i>Stephanocoenia intersepts</i>	Naval Pier Key West /03,04,06

Variable production costs (electricity, supplies, labor) were documented for the ECL tank systems. Electrical costs required to grow the corals were calculated based on kilowatt (kWh) hours per day for all of the equipment, lighting and air conditioning in the ECL and for the well-water pumping and well filtration system (Table 4). Other variable costs included food, replacement bulbs for metal halide lamps, chemicals for water chemistry and miscellaneous supplies. Labor was broken down by production task for both daily and cycle activities (Table 5). Fixed production costs are not presented because the ECL systems are located in an existing structure and available equipment was used to construct the tank and filtration systems.

The total variable costs associated with producing 1000 coral fragments (500 *Montastrea annularis* + 500 *Acropora cervicornis*) over a 6-month growing cycle in the ECL facility are estimated to be \$26,234 or \$26.23 per coral fragment. Growth rates for a 6-month period were estimated for each species based on optimal growth results in experimental growth trials conducted in the ECL. Initial stocking size for *Montastrea annularis* was 645 mm² (surface area) and harvest size for restoration after 6 months growth is estimated at 683 mm². Stocking size for *Acropora cervicornis* was 9 mm (height) and harvest size for restoration after 6 months growth is estimated at 43 mm.

We believe the high costs associated with space conditioning and lighting in ECL tanks is not cost effective production scenario for large-scale production of coral fragments for transplanting to field sites. However, the ECL tank systems are well suited for long-term maintenance of broodstock colonies for fragmentation, seed banking coral species, and controlled experimental trials. Large-scale production of coral fragments will require outdoor shade-cloth covered raceway systems or expanded raceways inside a ventilated greenhouse. In 2008, we expanded production of coral fragments for several species in the outdoor shade-cloth covered raceways at TRL (Figure 5 and 6). Culture requirements and strategies in this system are still being developed; however, preliminary results indicate that many of the key species can be grown in this environment.

Table 4. Estimated Electricity and Supply Costs for the Environmentally Controlled Laboratory (ECL) to Produce 1000 coral fragments (500 *Montastrea annularis* + 500 *Acropora cervicornis*).

Electricity & Supply Costs					
<u>Inputs</u>	<u>Units</u>	<u>Price</u>	<u>Quantity</u>	<u>Cost/day</u>	<u>Cost/cycle</u>
Electricity - ECL	kWh /day	\$0.135	94.8	\$12.80	\$2,336
Electricity - Well-water System	kWh /day	\$0.135	174	\$23.48	\$4,285
Food	\$/month	\$100	6		\$600
Light bulbs	\$/month	\$300	6		\$1,800
Chemistry supplies	\$/month	\$50	6		\$300
Miscellaneous supplies	\$/month	\$15	6		\$90
Total Electric & Supply Costs					\$9,411

Table 5. Estimated Labor Costs for the Environmentally Controlled Laboratory (ECL) to Produce 1000 coral fragments (500 *Montastrea annularis* + 500 *Acropora cervicornis*).

Production Task					
Daily Activities	hours/day	Cost/hour	Days/cycle	Cost /cycle	Total cost
Maintain filters	1	\$14	182.5	\$2555	
Clean tanks	2	\$14	182.5	\$5110	
Prepare food	0.5	\$14	182.5	\$1278	
Feed corals	0.5	\$14	182.5	\$1278	
Water chemistry	0.5	\$14	130	\$910	
Order supplies	0.1	\$14	130	\$182	
Measure corals	1	\$23	130	\$2990	
Total - Daily Activities	5.6				\$14,303
Cycle Activities	#	hours/day	# days	Cost/hr	Total Cost
Fragment corals	100 corals	8	10	\$14	\$1120
Make coral bases	100 bases	2	10	\$14	\$280
Mount corals on base	100 on base	8	10	\$14	\$1120
Total – Cycle Activities					\$2,520
Labor Total					\$16,823



Figure 5. Outdoor covered raceways.



Figure 6. Expanded coral production in outdoor raceways.

Task 3: Document the costs associated with replanting coral fragments to damaged reef sites in the Florida Keys.

Although corals were not replanted during this project, we have estimated the replanting costs for a hypothetical restocking of 1000 coral fragments from TRL tanks to a coral nursery site near Looe Key. We estimate that 50 corals can be replanted at the coral nursery site each day by a single diver. Therefore, 4 divers/technicians can replant 200 corals per day and it would take 5

days to replant all 1000 corals. The steps involved in stocking include moving the corals from the nursery tanks to coolers, transporting coolers on the boat from TRL to the nursery site, and having divers mount the coral bases and fragments at the nursery site. Costs could be reduced if more divers are involved or if more corals can be planted by individual divers.

Table 6. Estimated costs associated with restocking 1000 coral colonies from the Tropical Research Laboratory (Summerland Key) to a field nursery site near Looe Key.

Input	Units	Cost	Total Cost
Transportation - Boat	Boat Use = 5 days	\$225/day	\$1,125
Labor (transport, mounting)	4 technicians X 8 hr X 5 days	\$14/hr	\$2,240
Labor (Boat Captain)	Boat captain X 8 hr X 5 days	\$23/hr	\$920
Supplies (coolers, bags, O ² , epoxy)			\$40
Equipment use	Tank rental, dive gear		\$50
Total			\$4,375

Task 4: Provide staff, equipment, facilities and permits to perform the above mentioned tasks

Staffing was provided throughout this project to acquire corals, design, construct and maintain the ECL systems and laboratory, culture the corals in the ECL and outdoor raceway systems (feeding, cleaning, water chemistry, etc), conduct experimental growth trials, document and analyze growth, and provide educational outreach to visitors and the local community. An aquaculture permit was applied for and acquired annually to allow the culture of corals at TRL. Regular inspections were conducted by the State Department of Agriculture, Division of Aquaculture, to monitor compliance with Best Management Practices. An active FKNMS research and education permit was acquired and reports were submitted to comply with permit requirements.